**Effect of Vitamin D on muscle function and injury in elite adolescent dancers: a randomised double-blind study.**

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**Running Head:** Effect of Vit D on muscle function in young dancers

**Abstract**

**Purpose**: A number of studies have noted low levels of Vitamin D in dancers and this has been associated with increased risk of injuries and decreased muscular strength indices. The aim of the present study was to examine whether vitamin D supplementation over a 4-month period can improve muscle function and injury incidence.

**Methods**: Eighty-four participants volunteered, exclusion criteria and drop out (19%) reduced cohort to 67 (f=29, m=38; 17-19yrs). Participants were randomly assigned to either an intervention or placebo group (2:1 ratio). All provided a venous blood sample pre and post the 4-month study period. The intervention group received 120,000IU vitamin D to be taken over a 1-week period and the placebo group received the same number of inert pills. Participants completed a series of muscle function tests pre and post the monitoring period. Injury incidence was recorded by the independent health team at the school.

**Results:** Pre-intervention 6% of the cohort were vitamin D deficient, 81% were insufficient and 13% had sufficient levels; post-intervention 53% were insufficient and 47% were sufficient. The intervention group reported a significant increase in serum 25(OH)D3 (57%; $p<0.00$) and isometric strength (7.8%; $p=0.022$) but not muscular power. There was a significant association between traumatic injury occurrence for the intervention and control groups (10.9% vs. 31.8%; $p < .02$).

**Conclusion**: Vitamin D supplementation decreased the numbers of deficient and insufficient participants within this cohort. The intervention group reported a small significant increase in muscle strength that was negatively associated with traumatic injury occurrence.

## Introduction

The worldwide vitamin D deficiency has been frequently reported in the scientific literature over the past 20 years.[1] The majority of studies have focused on the adult population but the few that have used adolescent populations have reported similar deficiency and insufficiency rates.[2,3] This is of particular concern in this population as it coincides with adolescent growth spurt with the accompanying increase in skeletal maturation and muscle mass both of which are associated with optimal serum 25(OH)D levels.[4]

Very few foods naturally contain vitamin D and these foods are often insufficient to meet vitamin D needs in both children and adults.[5] The relatively limited amounts of dietary vitamin D can be obtained as either cholecalciferol (vitamin $D_3$ through oily fish and dairy products) or ergocalciferal (vitamin $D_2$ through plant extracts). Therefore, sun exposure in moderation is the major source of this vitamin for most humans and those who remain indoors during daylight are at increased risk of deficiency. This includes indoor athletes and previous research has reported increased incidence of vitamin D insufficiency/deficiency compared to outdoor athletes (80% vs. 48%).[6] Low serum 25(OH)D has been linked to reduced muscle strength and power which are fundamental to athletic performance[6,7]; this has further been associated with an increased incidence of injury.[8,9]

Vitamin D supplementation has become recommended practice in a number of sports including soccer, rugby union and judo. With all long-term supplementation, compliance issues can have an effect on the intended benefits.[10] As vitamin D is fat-soluble the benefits of a one -off large bolus intake rather than daily supplementation has been shown to be advantageous.[7] Previous studies in adult dancers have highlighted a high incidence of vitamin D insufficiency/ deficiency.[8] The benefits of supplementation within this population has shown improvement in muscle strength and power and an associated reduction in injury incidence.[9] Building on previous studies, the aim of the present study was to examine whether vitamin D supplementation can improve muscle function and injury incidence in adolescent elite dancers.

## Materials and methods

### Experimental design

The study implemented a randomised double-blind methodology. Supplementation was organised by an independent researcher who prepared the active and placebo tablets into numbered identical opaque tubs (1-90). At the time of the first test, the participants randomly chose a tub and the number was recorded against their participant code. The data collectors and the statistician were blind to participant's group (intervention or placebo) and only after the statistical analysis was completed were the group codes reviewed by the independent researcher.

### Participants

After the study received university ethical approval, one pre-professional dance school was approached for volunteers. Participants had all been in full-time vocational training since the age of 11 years old and were currently undergoing 33-36 hours of dance training a week, that included 1-2 hours of strength training and body conditioning (Pilates). Eighty-four participants initially volunteered for the study. Exclusion criteria included those under medical supervision for vitamin D deficiency, had serum values exceeding 120 $nmol/L^{-1}$, presently taking oral contraception, or were currently or had been injured in the last 3 months. There was a 19% participant drop out (n=17); 2 were excluded as pre-test serum 25(OH)D levels were above 120 $nmol/L^{-1}$; 3 were on medical supervision for low serum 25(OH)D and 12 dropped out of study or were unable to attend post intervention data collection. Seventy-one participants (age range 17-19) completed the study (table 1).

Table 1: Group participant descriptive information

| Group | Gender | Age (yrs) | Height (cm) | Mass (kg) |
|---|---|---|---|---|
| Intervention | Male (n=25) | 17 ±0.97 | 178.5 ±7.57 | 66.0 ±7.17 |
| (n=45) | Female (n=20) | 17 ±1.09 | 166.1 ±3.70 | 51.4 ±4.05 |
| Placebo | Male (n=13) | 17 ±0.97 | 177.9 ±3.68 | 65.1 ±5.28 |
| (n=22) | Female (n=9) | 17 ±0.50 | 167.5 ±4.38 | 54.1 ±4.97 |

**Protocol**
The data collection occurred at the beginning of January and the end of April 2017 at a latitude of 51.5$^{o}$N. Each participant completed an informed consent for and lifestyle questionnaire prior to anthropometric measurements and blood collection. Standing height was measured to the nearest 0.1cm using a Seca stadiometer (Hamburg, Germany), with the participants in bare feet and their heads positioned in the Frankfort horizontal plane. Total body mass was measured to the nearest 0.1 kg with a Seca beam balance 710 (Hamburg, Germany). A 5-7ml blood sample was collected into vacutainers which did not contain anticoagulants by a trained phlebotomist before being sent off for analysis to an independent laboratory.

Muscle function tests: Participants underwent familiarisation practices prior to the isometric mid-thigh pulls (IMTP) tests as they were already familiar with the muscular power tests. This consisted of 3-5 sub-maximal trials to correct technique. Muscle strength was measured via three 5-second isometric mid-thigh pulls (IMTP) using a strain gauge attached to PowerLab (AdInstruments, UK). The IMTP's handle was attached to a strain gauge by steel chain and then to a metal platform. The length of the chain was adjusted so that participants started in a half squat position with the handle was just above the knees and the arms straight and back flat, with feet parallel. Participants were instructed not to jerk but to quickly apply maximum force with their legs and lower back for a period of 5-seconds; there was 30-seconds of recovery between trials and the maximum force exerted was recorded. Muscular power was measured via counter movement jumps[CMJ] (both legs and single leg hops) and reactive strength index (RSI) calculated from a 30cm depth jump using an Optojump system (Microgate, Italy). Three trials of each condition were carried by all participants and the maximal scores recorded. The order of the power tests was randomised and there was a 5-minute rest between muscle strength and power testing.

Injury reporting: A time-loss definition of injury was used whereby "any injury that prevented a dancer from taking a full part in all dance related activities that would normally be required of them for a period equal to or greater than 24 h after the injury was sustained".[11] For the current study, injuries were further defined as either traumatic or overuse; a traumatic injury was defined as having a sudden, acute onset associated with a single incident, where as an overuse injury would have an insidious onset, often associated with load intolerance. Injuries were reported by in-house physiotherapists using Smartabase system (Fusion Sport, USA). The total number of injuries sustained by the participants over the four-month intervention period were recorded using the Orchard Sports Injury Classification System.

Vitamin D supplementation: The intervention group consumed 120,000IU of vitamin $D_3$ (120 tablets each containing 1000IU) and the placebo group consumed 120 inert tablets over a 4-day period. The tablets were indistinguishable in shape and size and were in identical tubs identifiable solely by a number (1-90).

**Statistical analysis**

Kolmogorov–Smirnov tests were initially performed to establish distribution of all the variables. Serum 25(OH)D3 levels, muscle strength and power were analysed using separate 3-way repeated-measures ANOVA with the between-subject factors being “treatment group” (intervention and placebo) and gender and the within-subject factor “time”. Chi-squared analysis was used to analyse injury incidence (total number of injuries, traumatic and overuse injuries) between the treatment groups. Significance for all tests was set at p≤0.05.

**Results**

Analysis of pre-intervention serum 25(OH)D3 levels indicated that 6% (n=4) of the cohort were deficient (<25 nmol.$L^{-1}$), 81% (n=52) were insufficient (25-75 nmol/$L^{-1}$) and 13% (n=18) had sufficient levels[12]; post-intervention 53% (n=35) were categorised as insufficient and 47% were above 75 nmol/$L^{-1}$. Between-subject factors reported a significant main effect for serum 25(OH)D3 for “time” (F=36.227, p=0.000) but not “gender” (p=0.893). Within-subject effects reported a significant effect for “time x treatment group” (F=14.796, p=0.000) but not “time x treatment group x gender” (p=0.979). The intervention group saw an increase of 57% in serum 25(OH)$D_3$ (58.41 ±24.58 to 83.39 ±23.74 nmol/$L^{-1}$) over the study period compared to 18% for the placebo group.

Table 2: Descriptive statistics for dependent variables pre and post intervention

| | | Pre | | Post | |
|---|---|---|---|---|---|
| | Gender (M=29, F=25) | Intervention (n=37) | Placebo (n=17) | Intervention (n=37) | Placebo (n=17) |
| Serum 25(OH)D (ng/$mL^{-1}$) | Male | 51.42 ±23.81 | 56.50 ±25.52 | 79.21 ±23.05 | 64.40 ±18.08 |
| | Female | 66.22 ±20.70 | 62.71 ±27.92 | 86.33 ±24.69 | 69.14 ±31.34 |
| Mid-thigh pull (N) | Male | 1315.9 ±328.0 | 1389.1 ±260.9 | 1399.3 ±179.1 | 1389.0 ±199.2 |
| | Female | 865.4 ±147.3 | 967.0 ±180.9 | 891.2 ±163.4 | 922.0 ±162.7 |
| Countermovement Jump (cm) | Male | 35.7 ±5.24 | 38.1 ±3.07 | 37.2 ±5.06 | 38.6 ±2.25 |
| | Female | 25.2 ±3.63 | 24.4 ±4.76 | 25.6 ±2.95 | 25.9 ±4.57 |
| Hop height Left (cm) | Male | 17.9 ±2.77 | 20.1 ±1.79 | 18.4 ±2.83 | 20.1 ±2.09 |
| | Female | 12.6 ±2.38 | 12.1 ±2.41 | 13.1 ±2.24 | 12.8 ±2.76 |
| Hop height Right (cm) | Male | 18.4 ±3.21 | 21.0 ±2.49 | 19.1 ±3.22 | 21.3 ±1.32 |
| | Female | 12.7 ±2.93 | 11.9 ±2.48 | 13.0 ±2.31 | 12.7 ±2.51 |
| Depth Jump (cm) | Male | 37.3 ±6.17 | 41.8 ±4.21 | 37.5 ±6.22 | 39.8 ±4.12 |
| | Female | 27.6 ±4.39 | 27.4 ±6.20 | 27.2 ±3.55 | 28.3 ±3.86 |
| RSI | Male | 1.49 ±0.254 | 1.76 ±0.243 | 1.57 ±0.255 | 1.78 ±0.259 |
| | Female | 1.14 ±0.352 | 1.12 ±0.291 | 1.11 ±0.264 | 1.21 ±0.174 |

There were significant gender differences in all the muscle power variables (p=0.000). Repeated measures analysis of the IMTP data reported no significant between-subject factors for “time” (p=0.311) or gender (p=0.494), but a significant within-subject effect for “time x treatment group” was reported (F=4.080; p=0.048). There was a significant percentage increase in newton force for the intervention group (7.8%; p=0.022) and a 1% decline for the placebo group. The observed change in force for the intervention group though statistically significant is too small to have a biological relevance. There were no significant observed changes for the muscle power variables: CMJ, Hop, Depth jump and RSI.

Table 3: Injury incidence and classification (% within group, % of all group)

| | | Frequency | | | |
|---|---|---|---|---|---|
| Injury | Group | 0 | 1 | 2 | 3 |
| Total | Intervention | 18 (42,74) | 21 (46,81) | 4 ( 9,39) | 2 (4,100) |
| | Placebo | 8 (36,26) | 6 (27,19) | 8 (36,62) | 0 (0,0) |
| Traumatic | Intervention | 40 (89,73) | 5 (11,42) | 0 | 0 |
| | Placebo | 15 (68,27) | 7 (32,58) | 0 | 0 |
| Overuse | Intervention | 21 (47,66) | 20 (44,74) | 4 (9,50) | 0 |
| | Placebo | 11 (50,34) | 7 (32,26) | 4 (18,50) | 0 |

Analysis of total injuries saw a significant association between occurrence of no injuries between the intervention group (40.0%) as compared to the placebo group (36.4%). There was a significant difference in the occurrence of injuries between the groups; the intervention group had significantly less participants incurring 2 injuries compared to the placebo group (intervention group, 8.9%; placebo group, 36.4%: $\chi^2$ (1) = 8.63, $p < .03$, $\varphi_c = .35$). Analysis of total traumatic injuries saw a significant association between occurrence of no traumatic injuries between the intervention group (88.9%) as compared to the placebo group (68.2%). More interestingly, there a significant occurrence of 1 traumatic injury between the intervention group (11.1.%) and the placebo group (31.8%). $\chi^2$ (1) = 4.30, $p < .03$, $\varphi_c = .25$. There was a significant association between occurrence of traumatic injuries when taking Vitamin D (10.9%) as compared to the occurrence of traumatic injuries while under control conditions (31.8%), $\chi^2$ (1) = 4.89, $p < .02$, $\varphi_c = .25$.

**Discussion**

Similar to the indoor athletes and dancers in Constantini et al[6] study, the results in this study found a high prevalence (87%) of vitamin D insufficiency (<75 nmol/$L^{-1}$). Adolescence is a vital period in musculoskeletal development and low levels of serum 25(OH)D during this growth phase will affect optimal growth[4,13], potentially being a cause of lower whole body bone mineral density observed in dancers compared to age matched controls.[14] Although ballet dancers are often considered to have amazing jumps, muscle strength and power data highlights that these physical attributes are underdeveloped compared to age-matched controls and athletes.[15] The limited comparison data for IMTP indicated that the present dance cohort produced maximum forces 50-70% of age and gender equivalent athletes.[16] The countermovement jump data were lower than that reported for normal adolescent populations[17], and significantly less for athletic populations.[16] This is partially explained by dancers' training, where the majority of time is spent on skill development (dance class and rehearsals) and any physical development is a secondary outcome to technique mastery.[18] Supplemental training, when it occurs, often takes the form of somatic techniques such as Pilates; there is little evidence that this type of exercise has beneficial effects on muscle function in trained populations.[19]

Three meta-analyses suggested limited benefits of vitamin D supplementation on muscle function to those who were deficient (<25 nmol/L)[20] or the benefits of supplementation were just limited to muscle strength.[21 22] The present study confirmed a small significant increase in muscle strength for the intervention group. Previous literature had suggested that vitamin D receptors were possibly type I fibre specific, but these studies involved elderly populations with sarcopenia[23] where type II fibres atrophy occurs at a greater rate than type I. Two recent studies have reported statistically significant but small improvements in muscle power (7-12%)[7,9] in adult ballet dancers taking vitamin D supplementation, though this was not replicated in the current study that reported 1-4% increases in CMJ. As previously mentioned, a possible explanation for the lack of change in CMJ could be because dancers' training, both technical and supplemental, rarely targets type II fibres, and therefore any targeting of vitamin D to type II fibres has little carryover effect to CMJ and other muscle power indices. This could explain the differences in power improvements in previous studies that reported 7% improvements in professional ballet dancers[9] compared to 12% in elite judokas.[7]

The reduced injury incidence in the intervention group could possibly be linked to the small increase in muscle strength observed in this group (7.8%). Muscle strength has been inversely linked to injury incidence[24] and this is especially true for dancers[9,25], that are significantly weaker than age-matched athletes as previously mentioned. The present study differentiated between traumatic and overuse injuries and noted lower numbers of traumatic for the intervention group. Although the cause of traumatic injury was not recorded in the present study, previous research in dance has highlighted landing from jumps as a major factor.[11,26] Improved muscular strength has been shown to protect against landing injuries[27,28] and therefore the improved strength indices for the intervention group could have acted as a protective mechanism.

The present study was limited by participant numbers and intervention time. Although the intervention group's serum 25(OH)D significantly increased, 36% were still classified as insufficient (50-75 nmol/$L^{-1}$) suggesting a need for a second bolus. This obviously would require a longer intervention period which wasn't possible in this study. Heaney and Holick[29] suggested that serum 25(OH)D levels need to be between 120-225 nmol.$L^{-1}$, though a recent meta-analysis suggested physical performance is not significantly improved.[30] The current study reported increases in serum 25(OH)D via vitamin D supplementation, the intervention group also demonstrated a limited increase in muscle strength and reduction in injury incidence. The data were from one vocational dance school in the UK and therefore further research needs to carried out in schools at different latitudes and diets, though research on Australian dance students found similar results[31].

**Practical applications**

Optimal vitamin D levels have been positively linked to widening health and physical performance benefits. Adolescence is an important growth period, insufficient or deficient nutrients during this period can have negative consequences. The current study suggests that adolescent dancers and indoor athletes should have their serum 25(OH)D levels monitored and be probably supplemented during winter months and possibly throughout the year.

**Conclusion**

Vitamin D supplementation significantly decreased the numbers of deficient and insufficient participants within this cohort. The intervention group reported a small significant increase in muscle strength that was negatively associated with traumatic injury occurrence.

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